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Standards-based reform across subject areas has an overarching goal of achieving high academic standards for all students. Although much is known about what constitutes high academic standards, little attention has been given to the attainment of educational equity for all students. In this article, we propose the notion of instructional congruence *as a way of making academic content accessible, meaningful, and relevant for diverse learners. Although our discussion considers students from non–English-language backgrounds (NELB) in science education, comparable approaches can be applied to other diverse student groups and other subject areas. We discuss an agenda for research, practice, and policy in promoting high standards for all students across subject areas.*

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Standards-based reform across subject areas has an overarching goal: high academic standards for all students (McLaughlin, Shepard, & O'Day, 1995; Smith & O'Day, 1991). Core components are emphasized for high academic standards across subject areas, including an understanding of key concepts and relationships, inquiry and problem-solving, communication and discourse, and dispositions or habits of mind in a discipline (Glaser & Linn, 1997; McLaughlin et al., 1995; National Council of Teachers of Mathematics, 1989; National Research Council, 1996).

Although research has provided a knowledge base for high standards of curriculum, instruction, and assessment across subject areas, the attainment of educational equity has received little attention. In fact, there is a great concern that "lack of support in reaching high standards will further victimize students already harmed by gross inequalities in the educational system" (McLaughlin et al., 1995, p. 68). In addition to questioning the nation's ability to meet the educational needs of its children, in her 1996 AERA presidential address, Linda Darling-Hammond emphasized the importance of creating a knowledge base so that all students can achieve high standards:

> What would it actually mean to teach all children to the high standards politicians talk about and educators are trying to fashion? What are the real educational implications of the school reform mantra "all children can learn"? What kinds of teaching practices support learning that enables higher levels of performance and understanding for different kinds of learners? . . . These are central research questions for the contemporary reinvention of democratic education. Their answers rest in part, I believe, on our growing ability to produce knowledge *for* and *with* educators and policymakers in ways that provide a foundation for a more complex form of teaching practice, one that attends simultaneously to students and their diverse needs on one hand and to the demands of more challenging subject matter standards on the other. (p. 8, original emphasis)

In this article, we discuss a process of promoting high academic standards for students from non–English-language backgrounds (NELB), an often underserved, yet rapidly growing population. We propose the notion of *instructional congruence* to indicate the process of mediating the nature of academic content with students' language and cultural experiences to make such content (e.g., science) accessible, meaningful, and relevant for diverse students (e.g., NELB students). The framework for instructional congruence for NELB students in science education integrates literacy and science to promote achievement in both areas (see Figure 1). We begin by explaining the framework of instructional congruence. Then we describe the components of instructional congruence, including the students, literacy, science, and teachers. We close the article by proposing an agenda for research, practice, and policy to promote high academic standards for all students. Although our discussion focuses on NELB students in science education, comparable approaches can be applied to other diverse student groups and other subject areas.

The Framework of Instructional Congruence

Traditionally, science has been taught with the expectation that students will understand and learn when teachers present the content in scientifically appropriate ways. In the framework in Figure 1, the emphasis has been on the left side of the science-literacy graphic with little consideration to students' literacy, language, and cultural understanding.

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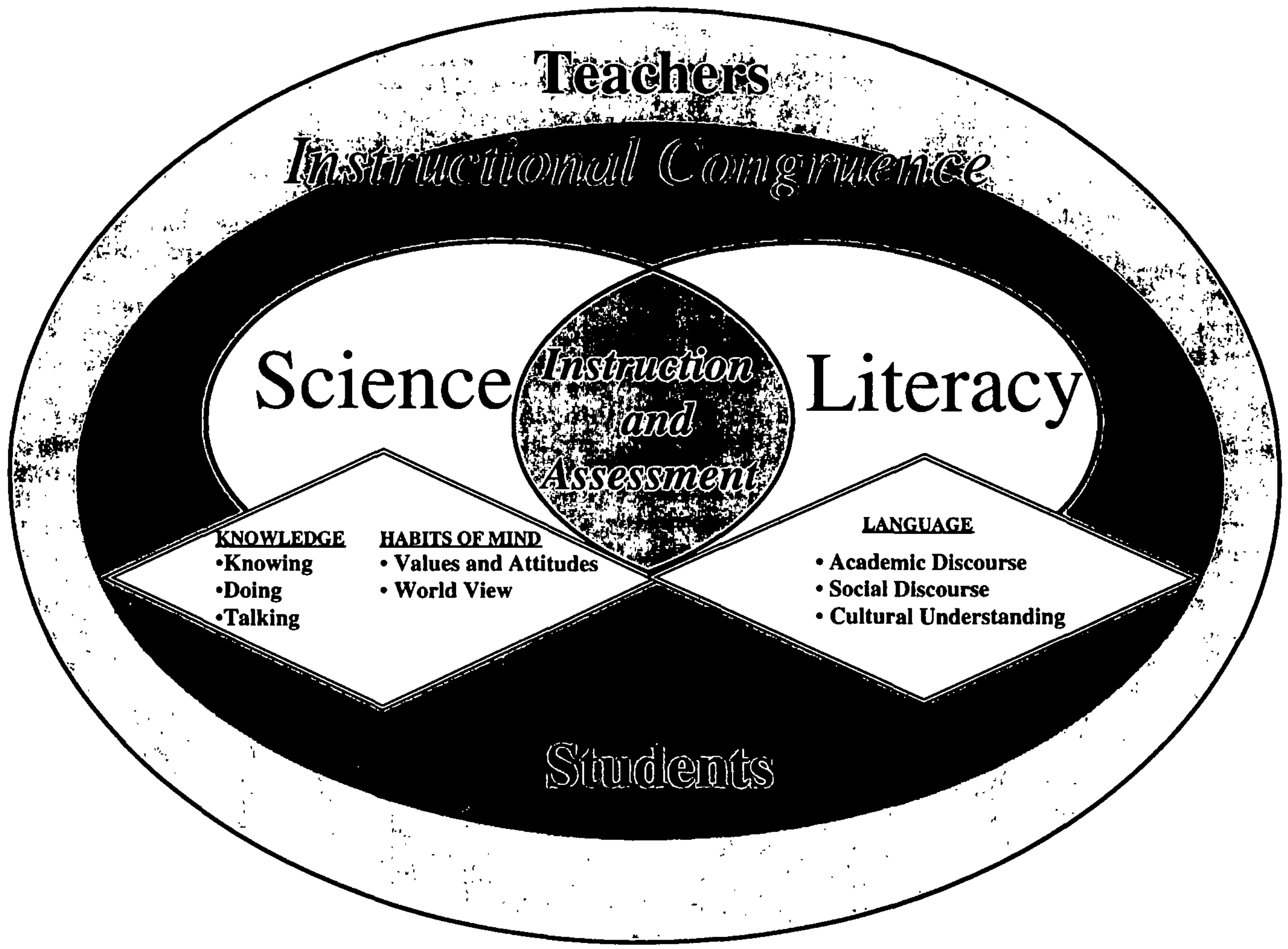

FIGURE 1. *Conceptual framework for instructional congruence in literacy and science.*

This practice may account, in part, for the underrepresentation and alienation of diverse students in science.

With the increasing diversity of the student population across the nation, there has been a growing interest in issues of culture and language in science instruction. Research on cultural congruence indicates that when teachers and students share languages and cultures, they tend to develop congruent ways of communicating and sharing understandings (Au & Kawakimi, 1994; Trueba & Wright, 1992; Villegas, 1991). Although cultural congruence may be a critical initial step in promoting students' attention and engagement, the students may not learn science unless teachers also understand the nature of science and know how to guide the students in developing an understanding of science (Fradd & Lee, 1995). In reference to the framework in Figure 1, cultural congruence typically stresses the right side of the science-literacy graphic, where teachers and students interact based on shared languages and cultures without a particular focus on the nature of subject areas (Saunders, Goldenberg, & Hamann, 1992; Tharp & Gallimore, 1988; Tuyay, Jennings, & Dixon, 1995).

To establish instructional congruence in science and literacy instruction for NELB students, teachers need to know (a) who the NELB students are, (b) how the students acquire literacy and English-language proficiency, (c) what the nature of science is and what kinds of language and cultural experiences the students bring to the learning process, and (d) how to guide and enable the students to understand science. Through the combined understanding of literacy and science, teachers can create a dynamic process that mutually supports both areas of learning (Fradd et al., 1997).

Students From Diverse Backgrounds

In recent decades, high sustained birth and immigration rates of students from diverse languages and cultures have made the need for effective instruction compelling (Improving America's Schools Act, 1994; U.S. Department of Commerce, 1993). During the past decade, as the overall percentage of monolingual English students in public schools has decreased, the NELB student population has increased (Waggoner, 1993). These demographic changes underscore the importance of identifying the challenges facing NELB students in learning science and the need for a comprehensive knowledge base to provide effective science instruction. In addressing the educational needs of NELB students, educators and policymakers face many difficulties. Three of these issues are (a) the terminology to refer to the students, (b) their ethnolinguistic identity, and (c) the lack of assessment information.

The terms used to identify and define NELB students have been problematic. In this article, we use "non-English-

language background" (NELB) to identify a specific population with many different home language backgrounds and varying levels of English-language proficiency. "Limited-English proficient" (LEP) is used by the U.S. Department of Education to refer to a portion of the NELB population unable to successfully participate in mainstream classrooms when English is the only language of instruction (Improving America's Schools Act, 1994). Considering that NELB students are the majority in many urban centers and a part of every state and most school districts, the term "language minority," although widely used, is not appropriate (U.S. Department of Commerce, 1993).

Ethnolinguistic identity presents another difficulty. The literature on ethnolinguistic diversity in the United States generally identifies five major categories: White, Black, Hispanic, Asian, and American Indian. Within each category, there are diverse language groups with different cultural experiences. Although the category of "Black" consists largely of African Americans, it also includes significantly different language groups from Caribbean, Latin American, and African countries. The "Asian" category consists of subgroups with different languages and cultures, including East Asians, Pacific Islanders, and Southeast Asians, who speak a variety of languages such as Khmer, Hmong, Lao, Vietnamese, Cantonese, Mandarin, Japanese, Korean, Tagalog, and Samoan. The "Hispanic" category includes learners whose primary language is usually Spanish or English, but whose cultures and ethnolinguistic heritages vary depending on whether they or their ancestors originated in the Americas, Europe, Africa, or even Asia. The term "Hispanic" has also been used to refer to indigenous people of Latin America who do not speak Spanish or English. The rather small population in the "American Indian" category includes over 100 language backgrounds. Although the majority speak only English, a proportion are bilingual (Lynch et al., 1996). Within the "White" category, there are students whose home languages are not English and who are from Canada, Brazil and other parts of Latin America, Europe, Africa, and the Middle East. Although commonalties can apply across groups and subgroups, generalizations about a particular ethnicity may obscure important differences. Differences in immigration history, socioeconomic status, acculturation within mainstream society, and family attitudes toward education all contribute to the diversity.

The process of identifying and meeting NELB students' educational needs is a challenge because information about students' achievement is not easily accessible or comparable across school districts (August & Hakuta, 1997; Fradd, 1987). Because large numbers of NELB students, particularly those designated as LEP, are exempted from state and district assessments used for accountability, little information is available about their academic performance (McLaughlin et al., 1995; Pérez-Hogan, 1996). Even less is known about what actually happens during instruction (Bernhardt, Teemant, & Rodriguez-Muñoz, 1995).

Literacy: Diverse Students' Languages and Cultures

NELB students' academic participation is influenced by their literacy development in home languages and in English. Key issues of literacy development and English-language proficiency in academic learning are discussed next.

Literacy Development

Literacy development involves abilities well beyond being able to speak, listen, read, and write. In the case of science instruction, it involves learning to observe, predict, analyze, summarize, and present information in a variety of formats, such as orally, in writing and drawing, and through tables and graphs.

Literacy development can be seen on a continuum from preliterate, with little or no schooling and exposure to literacy, to the age- and grade-appropriate development required for academic achievement. Within this continuum, students bring a wide range of literacy development to the science learning process. Important differences exist in the ways that students from preliterate and literate backgrounds use language and engage in science. For example, preliterate students or students developing literacy may have difficulty comprehending symbolic representations or associating them with real, three-dimensional objects. They may not distinguish explanations from descriptions and prefer repetitive statements to succinct communication. They may substitute gestures and nonspecific terms, such as "thing" and "stuff," for precise science terms (Lee, Fradd, & Sutman, 1995; Westby, 1995).

All students can benefit from learning experiences that enable them to use language functions, such as describing, hypothesizing, reasoning, explaining, predicting, reflecting, and imagining (Tough, 1986). Such functions are also important in science process and communication (Casteel & Isom, 1994). Preliterate students may require many concrete experiences and opportunities to use language functions in social settings before successfully applying them in academic contexts. Hands-on science activities offer important opportunities for social language development that can, in turn, provide the foundation for academic learning. Through these and other opportunities, students develop abilities for logic, reasoning, and critical thinking that are essential for both literacy and science learning.

Language Learning and English-Language Proficiency

In addition to general literacy development, NELB students must acquire English-language proficiency to effectively participate in mainstream classrooms. When English-language learning occurs at the expense of students' other language(s), the process becomes subtractive rather than additive as students lose their home languages. Not until the late 1960s and early 1970s did educators become aware of the cognitive benefits of developing literacy and proficiency in two or more languages (Lambert, 1977; Lambert & Anisfeld, 1969). Research, although limited, indicates that the use of students' home language promotes academic achievement in English (Tikunoff, 1985). In addition to academic advantages, bilingualism has recently been emphasized with respect to the workforce and global economy (Fradd & Boswell, 1996). Unfortunately, once students are determined to be "English-proficient," the use of other languages is often not considered in promoting achievement.

In addressing the educational needs of NELB students, most effort has focused on LEP students. The federal government does not specify which tests or procedures must be used to assess language proficiency, but allows the states and districts to determine the process (August & Hakuta, 1997). Decisions are often based on the length of time enrolled in bilingual and English for speakers of other languages (ESOL)

programs, rather than on academic achievement. Criteria for exiting students from ESOL programs frequently include standardized test scores comparable to the performance level of English-proficient students with learning disabilities (Fradd, 1987; Fradd & Larrinaga McGee, 1994).

When considered sufficiently proficient in English to participate in mainstream classrooms, NELB students may not pose apparent challenges. Often because they blend in, their teachers are unaware of language background differences or potential learning difficulties. When difficulties do occur, they may be attributed to misconduct or learning disabilities, rather than a need for language learning or an understanding of academic content (Fradd, 1987; Fradd & Larrinaga McGee, 1994).

Teachers are often unaware of distinctions between social and academic language (Cummins, 1984; Fradd & Larrinaga McGee, 1994). In school contexts, social discourse refers to the language used when participating in concrete, context-embedded interactions where students learn by observing, imitating, and interacting with others so that no single student is responsible for a particular outcome. In contrast, academic discourse, which is closely related to literacy development, refers to the language used in abstract, decontextualized activities requiring students to work independently, to rely on their own understandings of both the language and the content of the task, and to be singly responsible for an outcome. Teachers often do not understand task-demand differences between academic and social language and do not differentiate accordingly.

Science: Diverse Students in Learning Science

Science education standards documents (AAAS, 1989, 1993; NRC, 1996) represent a general agreement regarding high academic standards for curriculum, instruction, and assessment. According to these documents, science learning involves a two-part process "to acquire both scientific knowledge of the world and scientific habits of mind at the same time" (AAAS, 1989, p. 190; see Figure 1). The development of scientific knowledge involves "knowing" science (i.e., scientific understanding), "doing" science (i.e., scientific inquiry), and "talking" science (i.e., scientific discourse; see Table 1). The cultivation of scientific habits of mind includes scientific values and attitudes, as well as the scientific world view. These components of science learning have also been considered as general frameworks for some of the recent large-scale assessment projects, including the National Assessment of Educational Progress (National Assessment Governing Board, 1996) and the Third International Mathematics and Science Study (Martin & Kelly, 1996; Robitallie et al., 1993).

Although the standards documents generally define science in the Western science tradition (AAAS, 1989, p. 136; NRC, 1996, pp. 201, 204), alternative views have been advocated by scholars in the emerging areas of multicultural education, feminism, and sociology and philosophy of science (Atwater & Riley, 1993; Eisenhart, Finkel, & Marion, 1996; Hodson, 1993; Stanley & Brickhouse, 1994). These scholars raise issues of power and the marginalization of nonmainstream groups and challenge the basic notion of science and the traditionally defined meaning of scientific literacy.

Large-scale standardized test scores in science clearly indicate significant achievement gaps among ethnolinguistic groups (e.g., Mullis et al., 1994; National Center for Education Statistics, 1992; National Science Foundation, 1994). Although the goal of "science for all" is emphasized in reform documents (AAAS, 1989, 1993; NRC, 1996), current knowledge about science learning and achievement with NELB students is limited (August & Hakuta, 1997; Lynch et al., 1996). Despite a limited knowledge base, intervention programs in science instruction and curriculum have been implemented with NELB students, as evidenced by the large number of program evaluation reports, program descriptions, and teaching guides in the ERIC database (Lee, 1997). Most interventions seem to be based on intuition, rather than research-generated knowledge. Little information is available on the interventions' effectiveness in terms of what works and why.

A small body of literature has emerged recently as a result of heightened awareness of diversity and equity issues in science instruction. Notable examples include the work by Rosebery, Warren, and colleagues who observed Haitian and Hispanic students using open-ended scientific inquiry and analyzed their communication patterns (Rosebery, Warren, & Conant, 1992; Warren, Rosebery, & Conant, 1989). Fradd and Lee examined language performance, science knowledge, cognitive strategy use, and interactional patterns among monolingual English-speaking and bilingual Hispanic and Haitian students and teachers (Fradd & Lee, 1995; Lee & Fradd, 1996a, 1996b; Lee, Fradd, & Sutman, 1995). In addition to these small-scale research efforts, national centers on science teaching and learning also have addressed issues of diversity and equity, including the National Center for Science Teaching and Learning (e.g., Bernhardt et al., 1995; Donmoyer, 1995), the National Center for Cultural Diversity and Second Language Learning (e.g., Minicucci, 1996), and the National Institute for Science Education (e.g., Rodríguez, 1997).

This emerging body of research indicates various ways of knowing, doing, talking, expressing values and attitudes, and displaying habits of mind among diverse NELB groups. To promote science learning for NELB students, it is necessary to understand the nature and practice of science in combination with language and cultural experiences of NELB students. The matrix of the components of science learning as they relate to diverse NELB groups is presented in Table 1.

Each of the components of science learning is discussed with regard to the participation of NELB students. The intent is not to provide an exhaustive review, but to highlight key points for consideration in promoting science learning. Examples are provided from our own work as well as relevant literature. Several important issues should be noted. First, although members of a specific ethnolinguistic group may share common experiences, there are great variations among individuals within groups. Although valuable insights and heuristics about typical group patterns can be obtained, recognition of individual variation is also necessary. Second, although there are differences among diverse NELB groups, there are also commonalties across the groups. Third, rather than a set of monolithic outcomes, students' performance can be viewed as a process of developing literacy and English proficiency together with learning science that progresses along a continuum toward the attainment of high academic standards. Finally, there is a wide range of performance among NELB students, with

Table 1
Science Learning With Students From Non-English-Language Backgrounds

	Ethnolinguistic groups					
Components of science learning	Language group 1	Language group 2	Language group 3	Language group 4	Language group 5	Language group 6
Scientific knowledge						
Knowing science (scientific understanding)						
Building on prior knowledge						
Using appropriate science vocabulary						
Understanding concepts and relationships						
Doing science (scientific inquiry)						
Engaging in inquiry						
Solving real-world problems						
Talking science (scientific discourse)						
Participating in social and academic discourse						
Using multiple representational formats						
Appropriating the discourse of science						
Scientific habits of mind						
Scientific values and attitudes						
Manifesting generic values and attitudes						
Appropriating culturally mediated values and attitudes						
Scientific world view						
Recognizing scientific ways of knowing						

some doing well and many having difficulties. Successful students' achievement can provide insights for meeting the needs of less successful students.

Knowing Science

Knowing science involves making meaning of scientific knowledge and vocabulary. Prior knowledge and personal experience play key roles in acquiring new knowledge (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Posner, Strike, Hewson, & Gertzog, 1982). Learning and understanding occur when students successfully integrate new information with prior experience and construct new knowledge. The role of prior knowledge is especially important for NELB students. Because the knowledge students bring to the learning process may differ from the mainstream, identifying relevant experiences can play a major role in linking what students already know with what they are expected to learn (Atwater, 1994; Barba, 1993; Matthews & Smith, 1994; Rakow & Bermúdez, 1993). For example, NELB students would be familiar with metric systems of measurements, which can make an important contribution in science instruction.

Although vocabulary has traditionally played an important role in learning science (Lemke, 1990), science vocabulary is not a simple matter of a list of terms. Vocabulary learning, like language learning in general, is a complex process of developing relationships among ideas, terms, and meanings (Fradd & Larrinaga McGee, 1994). Appropriate use of key science terms is an indicator of the precision and sophistication of understanding (AAAS, 1993). Learning science vocabulary becomes more complex when comparable terms and parallel ways of considering ideas do not exist across languages. The words of one language cannot always be completely translated into another. Meanings must be understood within cultural contexts (Cobern, in press; Maddock, 1981). Even when comparable terms exist in two languages, they are often not used with the same frequency or in the same manner (Bialystok & Hakuta, 1994). As a result, students may circumlocute to convey meanings and produce large quantities of talk or utterances (Lee et al., 1995). By saying too much or too little, students may give the impression that they do not understand when they simply lack specific language or communication patterns to express precise meanings.

Doing Science

As a way of knowing science, students engage in inquiry, or doing science, by manipulating materials, making observations, proposing explanations, interpreting and verifying evidence, and constructing ideas to make sense of the world. Inquiry is the most emphasized component of science learning in the *National Science Education Standards* (NRC, 1996).

The emphasis on inquiry poses challenges for many NELB students. Students from oral language traditions may have difficulty using language functions, such as reflecting, predicting, inferencing, and hypothesizing (Casteel & Isom, 1994; Westby, 1995). Because of little formal schooling or the oral language traditions of the home, newly arrived students may experience difficulties with scientific inquiry in school because they have not been encouraged to ask questions or devise plans for investigation on their own (Trueba, Cheng, & Ima, 1993; Walker-Moffat, 1995). Students from cultures that respect authority may be

receptive to teachers telling and directing them, rather than to inquire, explore, and seek alternative ways.

Talking Science

Although knowing and doing have long been acknowledged as important components of science learning, recent reform emphasizes talking science. The *National Science Education Standards* (NRC, 1996) emphasizes, "[Teachers] structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse. A fundamental aspect of a community of learners is communication" (p. 50). Scientific modes of discourse for thinking, reasoning, and communicating are an area of research in science education (Gee, 1991; Lemke, 1990; Palincsar, Anderson, & David, 1993).

Language can serve to structure the ways that ideas are developed, organized, and communicated (Kaplan, 1986; Newman & Gayton, 1964). The social discourse of learning is often overlooked in science learning. Until recently, much of the communication about science has been done through reading and writing, as opposed to oral communication (Yore, Holliday, & Alverman, 1994). With a growing emphasis on younger and less literate learners, the role of oral discourse offers insight into ways that students relate to science and share their understanding with others.

Talking science is closely related to literacy development and representational fluency, involving written, pictorial, graphic, and electronic formats. Students with limited literacy experiences may initially have difficulty comprehending and using most representational formats. The appropriation of scientific discourse and the development of decontextualized, hypothetical reasoning can be facilitated using formats that do not require an explicit knowledge of verbal language. An example serves to illustrate the power of alternative formats in communicating ideas. A fourth-grade class of NELB students conducted an activity demonstrating the concept that when water freezes weight remains the same, although volume increases. A student who had difficulty writing expressed the concept by drawing two scales, one with a container of water and the other with a similar container of ice. He marked both scales with arrows showing that the weight stayed the same and made lines on the two containers showing the volume increased when the water turned to ice.

Communication patterns vary across languages and cultures (Cazden, 1988; Heath, 1983; Villegas, 1991). Students from diverse language backgrounds often have different interpretations of verbal communication and paralinguistic expression (Crowder & Newman, 1993; Lee & Fradd, 1996a). When communicating in English, NELB students may use the discourse patterns of their home languages. For example, some bilingual students use gestures to supplement and replace words and phrases more frequently than their monolingual English-speaking peers (Lee & Fradd, 1996a). Lengthy, repetitive, redundant talk that includes personal experiences and emotional reactions as well as science-related ideas occurs with some NELB groups (Moll, Díaz, Estrada, & López, 1992). Michaels and O'Connor (1990) describe a Haitian girl who had the concept of balance, but lacked the discourse pattern of "why-because" and the practice of making mental operations explicit. Although alternative communication patterns can provide NELB students with powerful ways of demonstrating their knowledge and understanding, these patterns may be ignored or even perceived as disruptive unless teachers recognize and value them.

Acquiring Scientific Attitudes and Values

Along with scientific inquiry and discourse, *National Science Education Standards* (NRC, 1996) emphasizes the nature of science as one of its key principles. Some scientific values and attitudes are found in most cultures, such as wonder, curiosity, interest, diligence, persistence, openness to new ideas, imagination, and respect toward nature. Other values and attitudes are characteristic of Western science, such as thinking critically and independently, reasoning, using empirical criteria, making arguments based on logic, questioning, openly criticizing, tolerating ambiguity, and demonstrating evidence rather than deferring to authority.

The importance of enabling students to acquire scientific values and attitudes while retaining their own cultural norms is an issue that requires careful consideration. Because science is largely defined in the tradition of Western science, the nature of science is more compatible with the cultural norms of the mainstream than those of diverse cultures. Using the notion of "border crossings," students have more difficulties crossing the cultural boundaries between their everyday world and the world of science when the discrepancies are greater (Aikenhead, 1996; O'Loughlin, 1992). For example, when students are taught to be in harmony and to function as a group, they may encounter great difficulty arguing their perspectives or critiquing others' ideas. Although the cultural norm of group cooperation often contrasts with individual and independent performance in the mainstream (Atwater, 1994; Lee & Fradd, 1996a; Tobin & McRobbie, 1996), both collaborative and individual performance are important in science learning. Mainstream and NELB students can equally benefit from learning each other's ways of participating in science.

Developing the Scientific World View

Science is a way of knowing that "distinguishes itself from other ways of knowing and from other bodies of knowledge" (NRC, 1996, p. 201). The nature of science in the standards documents is defined according to a tradition of seeking to understand how the world works (i.e., describe, explain, predict, and control natural phenomena). *National Science Education Standards* (NRC, 1996) clarifies the scientific world view as opposed to alternative views: "Explanations on how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific" (p. 201).

Although the distinction between the scientific world view and alternative views may be relatively straightforward to educated Westerners, children's world views involve a complex interaction of personal beliefs and scientific understanding (Loving, 1997). In addition, different cultural groups hold diverse, sometimes opposing, views about the social and natural world (Cobern, 1991; Hewson, 1988). Some groups tend to have mechanistic, instrumental views that seek to explain or control natural phenomena, whereas others express alternative views in which personal, social, and supernatural forces interact with natural phenomena. For example, in explaining the cause of a major hurricane they had personally experienced, mainstream

students often interpreted the phenomenon as a natural event, whereas NELB students expressed world views in which people and society (e.g., social ills of crime and violence), nature, and supernatural forces (e.g., God and devils) were all responsible (Lee, 1996). Because world views are shared belief systems in children's sociocultural environments, the scientific world view presents a challenging "border crossing" for diverse students (Cobern & Aikenhead, in press). Cultivation of the scientific world view, while recognizing and respecting alternative views, requires a great deal of sensitivity and consideration for both teachers and students.

Teachers' Roles in Establishing Instructional Congruence

To promote science learning for NELB students, an instructional approach is needed that establishes congruence between the nature of science and the language and cultural experiences of the students. Despite the central roles of teachers in "mediating between children's everyday world and the world of science" (Driver et al., 1994, p. 11), little consideration has been given to the background knowledge and experiences teachers bring to instruction. Instructional congruence for NELB students in science learning requires that teachers have (a) an understanding and appreciation of students' language and cultural experiences, (b) scientific knowledge and habits of mind, and (c) abilities to relate science to students' background experiences.

For teachers who share the languages and cultures of their students, having the same background knowledge can promote cultural congruence (Au & Kawakimi, 1994; Trueba & Wright, 1992). Implicit in the concept of cultural congruence is an understanding that teachers and students share and act on a set of unwritten rules and norms for interacting and communicating. The less English-proficient students are, the more cultural congruence plays a part in the instructional process. Cultural congruence, however, may also pose difficulties to both teachers and students because culturally congruent ways of knowing and communicating are sometimes incompatible with the nature of science as represented by science education standards.

When teachers identify with the science community but do not recognize the value of the languages and cultures students bring to the learning process, the teachers may have difficulty establishing instructional congruence. Without teachers' support for learning new ways of knowing, doing, and talking science, students may fail to relate to science and even actively resist learning it.

In an effort to build a foundation for instructional congruence with NELB students in science education, for the past five years, we have been working with three groups of elementary teachers who share the languages and cultures of their students: bilingual Hispanic and Haitian and monolingual English-speaking. Consistent with standards-based reform in science education, our work has focused on understanding key concepts and big ideas, inquiry, literacy and effective communication, and scientific habits of mind. Instead of asking the teachers to adopt one particular view of science instruction, we have encouraged them to teach science as they believe it would be most accessible, meaningful, and relevant for their students. Through this process, we have sought teachers' insights about how to relate science to students' language and cultural experiences.

Despite their commitment to effective instruction, the teachers initially expressed apprehension about their limited knowledge of science. As they became more knowledgeable about specific science content, they began to establish instructional congruence by relating their students' experiences to promote both science learning and language development (Fradd et al., 1997). A few examples illustrate the development of instructional congruence with these teachers.

In introducing the use of the thermometer, an Hispanic teacher wanted students to learn to read the Celsius and Fahrenheit scales. He posed the following questions: "When you have a fever, what temperature does your mother look for? What number does she expect to see on the thermometer?" Student responses varied from 38 to 40 and 98 to 100 degrees. While the students appeared puzzled by the range of numbers, the teacher responded, "Yes, that's right! Your mothers are taking your temperatures using two different scales, Celsius and Fahrenheit. Let's look at our thermometers. See the two scales? Our thermometers are bilingual, just like you." In this example, the teacher enabled students to recognize that two scales have equivalent ways of representing information. By relating the analogy of measurement systems with the students' language systems, the teacher linked students' experiences with big ideas of distinct but comparable systems.

In promoting an understanding of the water cycle, a Haitian teacher engaged the class in discussing the evaporation and condensation of water. In communicating their responses, students initially appeared to lack the necessary language to express their ideas clearly. As the teacher probed the students' responses, the discourse grew more comprehensive, moving from, "Condenses," and, "It condenses," to, "The water vapor condenses," and then, "The water vapor condenses as it cools." After further discussion, one student explained, "The hot water in the bottom cup evaporated to the top cup, where water vapor cooled with the ice and condensed in little drops." These discourse changes represent the intersection of language development and science learning. Initially, students learning English may use present tense verbs only without specified nouns and pronouns. As discourse becomes more complete, it also grows in complexity to include adverbs, adjectives, dependent clauses, and tense changes. While students describe and explain their observations in science activities, they acquire the discourse of literacy and the language of science.

Research on diverse ways of knowing, doing, and talking science is slowly emerging (Atwater, 1994). Although much remains to be learned about effective strategies to assist NELB students develop science knowledge, inquiry, and discourse (Fradd & Lee, 1995; Lee & Fradd, 1996a, 1996b; Rosebery et al., 1992; Warren et al., 1989), less is known about how to facilitate the cultivation of scientific habits of mind. For example, how can teachers enable students to use empirical standards, logical arguments, skepticism, questioning, and rules of evidence while maintaining cultural expectations of cooperation, social and emotional support, consensus-building, and respect for authority? Reconciling the nature of science with alternative habits of mind may be more challenging than the development of scientific knowledge. Because it promotes fundamental literacy development as practiced by the main-

stream, the cultivation of scientific habits of mind may be one of the most important contributions that science learning can offer.

An Agenda for Promoting Instructional Congruence

Science education reform emphasizes both excellence and equity for all students. Definitions of what constitutes scientific literacy remain ill-defined and elusive (Eisenhart et al., 1996; Kyle, 1995; Lee, 1997). Although educators seek to define and provide quality science instruction, limited attention has been given to equity. Achieving the goal of "science for all" requires the reconceptualization of fundamental issues of diversity and equity.

In this article, we have described dynamic relationships between the language and cultural backgrounds of students and teachers and the nature of science as proposed in science education reform. In establishing instructional congruence, teachers can build on students' background experiences while promoting new ways of understanding and communicating about academic subjects (Tikunoff, 1985). The difficulties inherent in establishing instructional congruence highlight the challenges of both science and language instruction. Recognition of diversity adds a new dimension to the discussion of individual and social construction of scientific knowledge (Driver et al., 1994) and emphasizes the complexity of science instruction in multilingual classrooms.

The importance of establishing instructional congruence underscores the need for further research. Small-scale investigations have been initiated in bilingual classrooms with teachers and students who share the same language and culture. This line of research needs to continue in bilingual classrooms with teachers and students of two different language and cultural backgrounds and, eventually, in multilingual classrooms. To effectively conceptualize and operationalize the research process, the integration of a variety of theoretical and methodological perspectives are required, including sociolinguistic, anthropological, cognitive science, subject matter expertise, and technological innovations. The results of these investigations could provide insights for enabling teachers to establish instructional congruence in science learning and language development for NELB students.

Close linkages are needed to support the efforts of teachers, researchers, policymakers, and the public in forming a strong, well-conceptualized agenda to promote academic achievement with NELB students. Teachers who share the languages and cultures of their students can offer practical insights and instructional applications that can be extended to classrooms where teachers do not share the languages of their students. In collaboration with researchers, teachers can contribute to the development of a knowledge base for promoting instructional congruence. The involvement of policymakers is essential in establishing effective programs, securing resources, and promoting public awareness of the importance of science for all students. The calls for excellence and equity emphasized in standards documents provide a platform for developing the policies, strategies, and programs that make the promise of "science for all" a reality. The case of science education with NELB students illustrates an opportunity to achieve high academic standards for all students across subject areas.

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References

Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education, 27*, 1–52.

American Association for the Advancement of Science (AAAS). (1989). *Science for all Americans*. New York: Oxford University Press.

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Atwater, M. M. (1994). Research on cultural diversity in the classroom. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 558–576). New York: Macmillan.

Atwater, M. M., & Riley, J. P. (1993). Multicultural science education: Perspectives, definitions, and research agenda. *Science Education, 77*, 661–668.

Au, K. H., & Kawakimi, A. J. (1994). Cultural congruence in instruction. In E. R. Hollins, J. E. King, & W. C. Hayman (Eds.), *Teaching diverse populations: Formulating a knowledge base* (pp. 5–24). Albany, NY: State University of New York Press.

August, D., & Hakuta, K. (Eds.). (1997). *Improving schooling for language-minority children: A research agenda*. Washington, DC: National Academy Press.

Barba, R. H. (1993). A study of culturally syntonic variables in the bilingual/bicultural science classroom. *Journal of Research in Science Teaching, 30*, 1053–1071.

Bernhardt, E., Teemant, A., & Rodriguez-Muñoz, M. (1995). *Science education and the second language learner*. Columbus, OH: The Ohio State University, The National Center for Science Teaching and Learning.

Bialystok, E., & Hakuta, K. (1994). *In other words: The science and psychology of second-language acquisition*. New York: Basic Books.

Casteel, C. P., & Isom, B. A. (1994). Reciprocal processes in science and literacy learning. *The Reading Teacher, 47*, 538–545.

Cazden, C. B. (1988). *Classroom discourse: The language of teaching and learning*. Portsmouth, NJ: Heinemann Educational Books.

Cobern, W. W. (1991). *World view theory and science education research* (NARST Monograph No. 3). Kansas State University, KS: The National Association for Research in Science Teaching.

Cobern, W. W. (in press). Worldview theory and conceptual change in science education. *Science Education*.

Cobern, W. W., & Aikenhead, G. S. (in press). Cultural aspects of learning science. In K. Tobin & B. Fraser (Eds.), *International handbook of science education*). London: Kluwer Academic Publishers.

Crowder, E. M., & Newman, D. (1993). Telling what they know: The role of gesture and language in children's science explanations. *Pragmatics and Cognition, 1*, 341–376.

Cummins, J. (1984). *Bilingualism and special education: Issues in assessment and pedagogy*. Boston: College-Hill.

Darling-Hammond, L. (1996). The right to learn and the advancement of teaching: Research, policy, and practice for democratic education. *Educational Researcher, 25*(6), 5–17.

Donmoyer, R. (1995). The rhetoric and reality of systemic reform: A critique of the proposed national science education standards. *Theory Into Practice, 34*, 30–34.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5–12.

Eisenhart, M., Finkel, E., & Marion, S. F. (1996). Creating the conditions for scientific literacy: A re-examination. *American Educational Research Journal, 33*, 261–295.

Fradd, S. H. (1987). The changing focus of bilingual education. In S. H. Fradd & W. J. Tikunoff (Eds.), *Bilingual education and bilingual special education: A guide for administrators* (pp. 1–44). Boston: Little, Brown.

Fradd, S. H., & Boswell, T. D. (1996). Spanish as an economic resource in metropolitan Miami. *Bilingual Research Journal, 20,* 283–338.

Fradd, S. H., & Larrinaga McGee, P. (1994). *Instructional assessment: An integrative approach to evaluating student performance.* Reading, MA: Addison-Wesley.

Fradd, S. H., & Lee, O. (1995). Science for all: A promise or a pipe dream for bilingual students? *The Bilingual Research Journal, 19,* 261–278.

Fradd, S. H., Lee, O., Cabrera, P., del Rio, V., Leth, A., Morin, R., Ceballos, M., Santalla, M., Cross, L., & Mathieu, T. (1997). School-university partnerships to promote science with students learning English. *TESOL Journal,* 35–40

Gee, J. P. (1991). What is literacy? In C. Mitchell & K. Weiler (Eds.), *Rewriting literacy: Culture and the discourse of the other* (pp. 3–12). New York: Bergin & Garvey.

Glaser, R., & Linn, R. (1997). *Assessment in transition: Monitoring the nation's educational progress.* Stanford, CA: Stanford University, The National Academy of Education.

Heath, S. B. (1983). *Ways with words: Language, life, and work in communities and classrooms.* New York: Cambridge University Press.

Talking science is closely related to literacy development and representational fluency, involving written, pictorial, graphic, and electronic formats.

Hewson, M. G. (1988). The ecological context of knowledge: Implications for learning science in developing countries. *Journal of Curriculum Studies, 20,* 317–326.

Hodson, D. (1993). In search of a rationale for multicultural science education. *Science Education, 77,* 685–711.

Kaplan, R. B. (1986). Culture and the written language. In J. M. Valdes (Ed.), *Culture bound: Bridging the cultural gap in language teaching* (pp. 8–19). New York: Cambridge University Press.

Kyle, W. C. (1995). Scientific literacy: How many lost generations can we afford? *Journal of Research in Science Teaching, 32,* 895–896.

Lambert, W. E. (1977). The effects of bilingualism on the individual: Cognitive and sociocultural consequences. In P. S. Hornby (Ed.), *Bilingualism: Psychological, social, and educational implications* (pp. 15–27). New York: Academic Press.

Lambert, W. E., & Anisfeld, E. (1969). A note on the relationship of bilingualism and intelligence. *Canadian Journal of Behavioral Science, 1,* 123–128.

Lee, O. (1996). Children's science conceptions and world views in social and cultural contexts: Making sense after Hurricane Andrew. In S. Sayre & D. Horne (Eds.), *Earth, wind, fire and water: Approaching natural disaster* (pp. 197–221). Pasadena, CA: Open Door Publishers.

Lee, O. (1997). Science literacy for all: What is it, and how can we achieve it? *Journal of Research in Science Teaching, 34,* 219–222.

Lee, O., & Fradd, S. H. (1996a). Interactional patterns of linguistically diverse students and teachers: Insights for promoting science learning. *Linguistics and Education: An International Research Journal, 8,* 269–297.

Lee, O., & Fradd, S. H. (1996b). Literacy skills in science performance among culturally and linguistically diverse students. *Science Education, 80,* 651–671.

Lee, O., Fradd, S. H., & Sutman, F. X. (1995). Science knowledge and cognitive strategy use among culturally and linguistically diverse students. *Journal of Research in Science Teaching, 32,* 797–816.

Lemke, J. L. (1990). *Talking science: Language, learning, and values.* Norwood, NJ: Ablex Publishing.

Loving, C. C. (1997). From the summit of truth to its slippery slopes: Science education's journey through positivist-postmodern territory. *American Educational Research Journal, 34,* 421–452.

Lynch, S., Atwater, M., Cawley, J., Eccles, J., Lee, O., Marrett, C., Rojas-Medlin, D., Secada, W., Stefanich, G., & Wiletto, A. (1996). *An equity blueprint for Project 2061 science education reform: Second draft.* Washington, DC: American Association for the Advancement of Science, Project 2061.

Maddock, M. N. (1981). Science education: An anthropological view point. *Studies in Science Education, 8,* 1–26.

Martin, M. O., & Kelly, D. L. (Eds.). (1996). *Third International Mathematics and Science Study technical report. Vol. 1: Design and development.* Chestnut Hill, MA: Boston College, Center for the Study of Testing, Evaluation, and Educational Policy.

Matthews, C. E., & Smith, W. S. (1994). Native American related materials in elementary science instruction. *Journal of Research in Science Teaching, 31,* 363–380.

McLaughlin, M. W., Shepard, L. A., & O'Day, J. A. (1995). *Improving education through standards-based reform: A report by the National Academy of Education Panel on Standards-Based Education Reform.* Stanford, CA: Stanford University, The National Academy of Education.

Michaels, S., & O'Connor, M. C. (1990). *Literacy as reasoning within multiple discourses: Implications for policy and educational reform.* Paper presented at the Council of Chief State School Officers Summer Institute on Restructuring Learning, Education Development Center, Literacies Institute, Newton, MA.

Minicucci, C. (1996). *Learning science and English: How school reform advances science learning for limited English proficient middle school students.* Santa Cruz, CA: University of California, National Center for Research on Cultural Diversity and Second Language Learning.

Moll, L. C., D!az, S., Estrada, E., & López, L. M. (1992). Making contexts: The social construction of lessons in two languages. In M. Saravia-Shore & S. Arvizu (Eds.), *Cross-cultural literacy: Ethnographies of communication in multiethnic classrooms* (pp. 339–366). New York: Garland.

Mullis, V. S., Dossey, J. A., Campbell, J. R., Gentile, C. A., O'Sullivan, C., & Latham, A. S. (1994). *NAEP 1992 trends in academic progress.* Washington, DC: Educational Testing Service, under contract with the National Center for Education Statistics, Office of Educational Research and Improvement, U.S. Department of Education.

National Assessment Governing Board (NAGB). (1996). *Science framework for the 1996 National Assessment of Educational Progress: NAEP Science Consensus Project.* Washington, DC: Author.

National Center for Education Statistics (NCES). (1992). *Language characteristics and academic achievement: A look at Asian and Hispanic eighth graders in NELS: 1988.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

National Council of Teachers of Mathematics (NCTM). (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

National Research Council (NRC). (1996). *National science education standards.* Washington, DC: National Academy Press.

National Science Foundation (NSF). (1994). *Women, minorities, and persons with disabilities in science and engineering: 1994* (NSF-94-333). Arlington, VA: Author.

Newman, S. S., & Gayton, A. H. (1964). Yokuts narrative style. In D. Hymes (Ed.), *Language in culture and society* (pp. 372–381). New York: Harper & Row.

O'Loughlin, M. (1992). Rethinking science education: Beyond Piagetian constructivism toward a sociocultural model of teaching and learning. *Journal of Research in Science Teaching, 29,* 791–820.

Palincsar, A. S., Anderson, C. W., & David, Y. (1993). Pursuing scientific literacy in the middle grades through collaborative problem solving. *The Elementary School Journal, 93,* 643–658.

Pérez-Hogan, C. (1996, December). *NYS assessment program for LEP students—a proud history and a new beginning.* Paper presented at the Invitational Roundtable on the Implications of the New Standards and High Stakes Assessments for Limited English Proficient Students, New York.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66,* 211–227.

Rakow, S. J., & Bermúdez, A. B. (1993). Science is "ciencia": Meeting the needs of Hispanic American students. *Science Education, 77,* 669–683.

Robitallie, D. F., McKnight C., Schmidt, W. H., Britton, E., Raizen, S., & Nicol, C. (1993). *TIMSS Monograph No. 1. Curriculum frameworks for mathematics and science.* Vancouver, CA: Pacific Educational Press.

Rodríguez, A. (1997). The dangerous discourse of invisibility: A critique of the NRC's National Science Education Standards. *Journal of Research in Science Teaching, 34,* 19–37.

Rosebery, A. S., Warren, B., & Conant, F. R. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *The Journal of the Learning Sciences, 21,* 61–94.

Saunders, W., Goldenberg, C., & Hamann, J. (1992). Instructional conversations beget instructional conversations. *Teaching and Teacher Education, 8,* 199–218.

Smith, M. S., & O'Day, J. (1991). Systemic school reform. In S. H. Fuhrman & B. Malen (Eds.), *The politics of curriculum and testing: The 1990 yearbook of the Politics of Education Association* (pp. 233–267). Bristol, PA: Falmer Press.

Stanley, W., & Brickhouse, N. (1994). Multiculturalism, universalism, and science education. *Science Education, 28,* 387–398.

Tharp, R., & Gallimore, R. (1988). *Rousing minds to life: Teaching, learning and schooling in context.* Cambridge, UK: Cambridge University Press.

Tikunoff, W. J. (1985). *Applying significant bilingual instructional features in the classroom.* Arlington, VA: National Clearinghouse for Bilingual Education.

Tobin, K., & McRobbie, C. J. (1996). Significance of limited English proficiency and cultural capital to the performance in science of Chinese-Australians. *Journal of Research in Science Teaching, 33,* 265–282.

Tough, J. (1986). *Talk two: Children using English as a second language in primary schools.* Portsmouth, NH: Heinemann.

Trueba, H. T., Cheng, L., & Ima, K. (1993). *Myth or reality: Adaptive strategies of Asian Americans in California.* New York: The Falmer Press.

Trueba, H. T., & Wright, P. G. (1992). On ethnographic studies and multicultural education. In M. Saravia-Shore & S. Arvizu (Eds.), *Cross-cultural literacy: Ethnographies of communication in multiethnic classrooms* (pp. 299–338). New York: Garland.

Tuyay, S., Jennings, L., & Dixon, C. (1995). Classroom discourse and opportunities to learn: An ethnographic study of knowledge construction in a bilingual third-grade classroom. *Discourse Processes, 19,* 75–110.

U.S. Department of Commerce. (1993). *1990 profiles of the foreign-born population, selected characteristics by place of birth* (CPH-L-148). Washington, DC: Author.

Villegas, A. M. (1991). *Culturally responsive pedagogy for the 1990s and beyond.* Washington, DC: ERIC Clearinghouse on Teacher Education, American Association of Colleges for Teacher Education.

Waggoner, D. (1993). The growth of multilingualism and the need for bilingual education: What do we know so far? *The Bilingual Research Journal, 17,* 1–12.

Walker-Moffat, W. (1995). *The other side of the Asian American success story.* San Francisco, CA: Jossey-Bass Publishers.

Warren, B., Rosebery, A. S., & Conant, F. R. (1989). *Cheche konnen: Science and literacy in language minority classrooms.* Newton, MA: Bolt, Beranek, & Newman.

Westby, C. E. (1995). Culture and literacy: Frameworks for understanding. *Topics in Language Disorders, 16,* 50–66.

Yore, L. D., Holliday, W. G., & Alverman, D. E. (Eds.). (1994). The reading-science learning-writing connection (Special Issue). *Journal of Research in Science Teaching, 31,* 873–1073.

Statutes

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President-Elect Invites Suggestions

Each year, the AERA president appoints a number of members to committees that are important to the association. The committees include Publications; Professional Development and Training; Governmental and Professional Liaison; Special Interest Groups; Role and Status of Women; Role and Status of Minorities; Nominations; Research, Policy, and Practice; International Relations; *JEBS* Management; Annual Meeting; Professional Outreach; Telecommunications; Minority Fellowship Selection; and seven annual award committees.

This year, President-Elect Lorrie A. Shepard hopes to form many of the committees before the annual meeting in Montreal. She urges members to supply names, including their own, if they are interested in serving on a committee. Please send a resume if volunteering (or a statement about qualifications if nominating someone else) and state which committees are of interest.

She also welcomes suggestions about existing AERA programs and possible new initiatives. Please write to her at

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